Concrete in Practice
What, why & how?
NRMCA

CIP 40 - Aggregate Popouts

WHAT is Popout?

A "popout" is a small, generally cone-shaped cavity in a horizontal concrete surface left after a near-surface aggregate particle has expanded and fractured. Generally, part of the fractured aggregate particle will be found at the bottom of the cavity with the other part of the aggregate still adhering to the point of the popout cone. The cavity can range from ¼ in. (6 mm) to few inches in diameter.

WHY do Concrete Popouts Occur?

The aggregate particle expands and fractures as a result of a physical action or a chemical reaction:

Physical

The origin of a physical popout usually is a near-surface aggregate particle having a high absorption and relatively low relative density (specific gravity). As that particle absorbs moisture; or if freezing occurs under moist conditions, its swelling creates internal pressures sufficient to rupture the particle and the overlying concrete surface. The top portion of the fractured aggregate particle separates from the concrete surface taking a portion of the surface mortar with it. In some cases the aggregate forces water into the surrounding mortar as it freezes thus causing the surface mortar to pop off, exposing an intact aggregate particle. Clay balls, coal, wood or other contaminants can uptake water and swell even without freezing, but the resulting pressure rarely is great enough to cause popouts. Also, there are reported cases of grain (soybeans, corn) contamination of aggregate shipments that have resulted in surface popouts. Such occurrences are not within the scope of this document.

Popouts as a result of physical action are typically only a problem with exterior flatwork in climates subject to freezing and thawing under moist conditions and resulting expansion. Even aggregates which meet the requirements of ASTM C 33 Class 5S, for architectural concrete in severe exposure, allow several types of particles which may cause popouts when exposed to freezing and thawing in the saturated condition. The most common type of particles resulting in popouts are low density chert in natural aggregate deposits.

Aggregate Popout

Courtesy PCA

Crushed aggregates are less likely to contain lightweight, absorptive particles which are more susceptible to popouts.

Chemical

The cause of a popout due to a chemical reaction is often related to alkali-silica reaction (ASR). Alkalis from cement or other source cause an environment of high pH (high concentrations of OH ions) causing the breakdown of silica and formation of an ASR gel, which absorbs water and expands, removing a small portion of the surface mortar with it. These are called ASR Popouts. They are typically small and are often accompanied by a small spot that is discolored and/or appears to be damp. The aggregate particle does not often fracture and split as is the case of popouts from physical action. However, the ASR phenomenon can result in micro-fractures within the aggregate particles. Some alkali-silica reaction popouts can occur within a few days after the concrete is placed.

HOW to Avoid Concrete Popouts?

Most popouts are aesthetic defects that do not impact the structural performance of the concrete members. A large number of popouts however make it easier for water and other harmful chemicals to enter the concrete, which can ultimately lead to other forms of deterioration such as corrosion of steel reinforcement. The following steps can be taken to avoid concrete popouts.

Physical Popouts

1. Avoid using aggregates which contain particles which may cause popouts, or that have a history of popouts. However, in some parts of the United States, the available natural gravels contain some particles that are likely to result in surface popouts. Due to the unavailability of economical alternate aggregates, the occurrence of popouts on sidewalks and pavements is an accepted , albeit undesirable, likelihood in those locations.
2. If popouts are unacceptable, an alternate source of aggregates must be located. If appropriate, two-course construction can be used, whereby the popout susceptible aggregate is used for the lower course and the pop-out free aggregat that is likely to be more expensive is used for the surface course.
3. Aggregates can be beneficiated to remove lightweight materials, but the added cost of beneficiation can be prohibitive for most uses.
4. Reduce the water to cementitious materials ratio of the concrete, as this will reduce the likelihood of saturation and will increase the resistance to swelling forces. Provide proper curing for exterior flatwork, as this results in improved strength of the cementitious materials, especially on the surface. This will reduce permeability thereby lowering the amount of water migrating to coarse aggregate particles. These steps can reduce the frequency, but will not necessarily, eliminate popouts.
5. Reduce the maximum aggregate size, as smaller aggregates will develop lower stresses due to freezing, and fewer popouts will occur. Those that do will be smaller and less objectionable.

Chemical Popouts

1. Use a low-alkali cement or a non-reactive aggregate. This is often not a practical option in many regions
2. Flush the surfaces with water after the concrete has hardened and before applying the final curing. This will remove the alkalis that may have accumulated at the surface as a result of evaporation of bleed water.
3. Permit the use of Class F fly ash or slag cement as a partial cement substitute to reduce the permeability of the paste and mitigate deleterious reactions due to ASR.

HOW to Repair Concrete Popouts?

Prior to undertaking a repair program, it is advisable to confirm the cause of the popouts by obtaining core samples containing one or more typical popouts and having them studied by a qualified petrographer.

Popouts can be repaired by chipping out the remaining portion of the aggregate particle in the surface cavity, cleaning the resulting void, and by filling the void with a proprietary repair material such as a dry pack mortar, epoxy mortar, or other appropriate material following procedures recommended by the manufacturer. It will be difficult to match the color of the existing concrete. If the popouts in a surface are too numerous to patch individually, a thin bonded concrete overlay may be used to restore a uniform surface appearance. Specific recommendations for such overlays are beyond the scope of this publication.

References

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